

55 CLAIMS:

1 1. A system for measuring parameters of a structure,
2 the system comprising

3 a plurality of strain gauges emplaceable on the
4 structure,

5 signal transmission apparatus associated with
6 the plurality of strain gauges for transmitting signals
7 therefrom indicative of measurements by the plurality of
8 strain gauges to computer apparatus for processing
9 signals from the strain gauges,

10 the plurality of strain gauges including at
11 least three strain gauge apparatuses for providing
12 axial strain measurements at each location of one of the
13 at least three strain gauge apparatuses, and

14 computer apparatus for receiving signals from
15 the transmitting apparatus indicative of the measurements
16 of the at least three strain gauge apparatuses and for
17 determining, based on said measurements, bending moment
18 of the structure at a location of a plane including the
19 at least three strain gauge apparatuses.

1 2. The system of claim 1 wherein the computer apparatus
2 is programmed to calculate internal pressure of the
3 structure based on strain measurements from the plurality of
4 strain gauges.

1 3. The system of claim 1 wherein the computer apparatus
2 is programmed to calculate bending direction of the
3 structure at said location based on said measurements.

1 4. The system of claim 1 wherein the computer apparatus
2 determines bending moment in real time.

1 5. The system of claim 4 wherein the computer apparatus
2 is programmed to make a plurality of continuous determinations
3 of bending moment in real time.

1 6. The system of claim 1 further comprising
2 encasement material encasing the plurality of strain gauges.

1 7. The system of claim 6 wherein the encasement
2 material comprises insulating material for enhancing
3 uniformity of operation of the plurality of strain gauges
4 during temperature changes.

1 8. The system of claim 6 wherein the encasement
2 material comprises potting material.

3 9. The system of claim 1 further comprising
1 each of the plurality of strain gauges
2 comprises a fiber optic strain gauge.

3 10. The system of claim 1 further comprising
4 display apparatus for displaying to an operator
1 determinations of the computer apparatus.

1 11. The system of claim 1 further comprising
2 alarm apparatus for warning an operator of the
3 system that a maximum allowable stress on the structure has
4 been reached, the computer apparatus programmed to calculate
5 maximum allowable stress and in communication with the alarm
6 apparatus.

1 12. The system of claim 1 further comprising
2 temperature measurement apparatus for measuring
3 temperature of the structure at the location of plurality of
4 strain gauges.

5 13. The system of claim 12 wherein the temperature
6 measurement apparatus comprises fiber optic strain gauge
7 apparatus for measuring temperature.

1 14. The system of claim 12 wherein the computer
2 apparatus is programmed to adjust said measurements for
3 temperature changes indicated by the temperature measurement
4 apparatus.

1 15. The system of claim 12 wherein the system includes
2 temperature measurement apparatus for measuring temperature of
3 the structure at the location of the plurality of strain
4 gauges, pressure measurement apparatus for measuring internal
5 pressure of the structure, and weight measurement apparatus
6 for measuring weight of the structure; and the computer

7 apparatus is programmed to receive signals indicative of
8 strain measurements from the plurality of strain gauges,
9 temperature measurements from the temperature measurement
10 apparatus, internal pressure measurements from the pressure
11 measurement apparatus, and weight measurement from the weight
12 measurement apparatus, and the computer apparatus is
13 programmed to determine bending moment of the structure at the
14 location of the plurality of strain gauges, stresses
15 throughout the structure, maximum stress on the structure, and
16 location of maximum stress on the structure.

1 16. The system of claim 1 wherein the plurality of
2 strain gauges comprises at least one set of three fiber optic
3 strain gauges including an axial strain gauge for measuring
4 axial stress on the structure, a hoop strain gauge for
5 measuring hoop stress on the structure, and a temperature
6 strain gauge for measuring temperature of the structure.

1 17. The system of claim 16 wherein the at least one set
2 of three fiber optic strain gauges is four sets spaced at
3 ninety 90 degree intervals around the structure.

1 18. The system of claim 1 wherein the structure is from
2 the group consisting of riser, subsea riser, lubricator, pipe
3 support structure, tubular string, and lubricator stack.

1 19. The system of claim 1 further comprising
2 a protective ring apparatus on the structure
3 adjacent which is located the plurality of strain gauges.

4 20. The system of claim 19 wherein the protective ring
5 apparatus is two spaced-apart rings between which are located
6 the plurality of strain gauges.

7 21. The system of claim 19 wherein potting material
8 encapsulates the plurality of strain gauges.

9 22. The system of claim 1 further comprising
10 cover apparatus releasably connected to the
11 structure over the plurality of strain gauges.

13 23. A method for measuring parameters of a structure,
14 the method comprising

15 measuring parameters of the structure with a
16 system, the system comprising a plurality of strain gauges
17 emplaceable on the structure, signal transmission apparatus
18 associated with the plurality of strain gauges for
19 transmitting signals therefrom indicative of strain
20 measurements by the plurality of strain gauges to computer
21 apparatus for processing signals from the strain gauges, the
22 plurality of strain gauges including at least three strain
23 gauge apparatuses for providing axial strain measurements at
24 each location of one of the at least three strain gauge
25 apparatuses, and computer apparatus for receiving signals from
26 the transmitting apparatus indicative of the measurements of
27 the at least three strain gauge apparatuses and for
28 determining, based on said measurements, bending moment of the
29 structure at a location of a plane including the at least
30 three strain gauge apparatuses.

31 24. The method of claim 23 wherein the computer
32 apparatus is programmed to calculate internal pressure of the
33 structure based on strain measurements from the plurality of
34 strain gauges, the method further comprising

35 with the computer apparatus, calculating said
36 internal pressure.

1 25. The method of claim 23 wherein the computer
2 apparatus is programmed to calculate bending direction of the
3 structure at said location based on said measurements, the
4 method further comprising

5 with the computer apparatus, calculating said
6 bending direction.

1 26. The method of claim 23 wherein the computer
2 apparatus determines bending moment in real time, the method
3 further comprising

4 with the computer apparatus, determining said

5 bending moment in real time.

1 27. The system of claim 26 wherein the computer
2 apparatus is programmed to make a plurality of continuous
3 determinations of bending moment in real time, the method
4 further comprising

5 with the computer apparatus, making said plurality
6 of continuous determinations in real time.

1 28. The method of claim 23 wherein the computer
2 apparatus is programmed to calculate bending direction of the
3 structure at said location based on said measurements and
4 wherein the system includes temperature measurement apparatus
5 for measuring temperature of the structure at the location of
6 the plurality of strain gauges, pressure measurement apparatus
7 for measuring internal pressure of the structure, and weight
8 measurement apparatus for measuring weight of the structure;
9 and the computer apparatus is programmed to receive signals
10 indicative of strain measurements from the plurality of strain
11 gauges, temperature measurements from the temperature
12 measurement apparatus, internal pressure measurements from the
13 pressure measurement apparatus, and weight measurement from
14 the weight measurement apparatus, and the computer apparatus
15 is programmed to determine, in real time, bending moment of
16 the structure at the location of the plurality of strain
17 gauges, stresses throughout the structure, maximum stress on
18 the structure, and location of maximum stress on the
19 structure, the method further comprising

20 with the computer apparatus, calculating in real
21 time said bending direction, said bending moment, said
22 stresses throughout the structure, said maximum stress, and
23 said location of said maximum stress.

1 29. The method of claim 28 wherein the said bending
2 direction, said bending moment, said stresses throughout the
3 structure, said maximum stress, and said location of said
4 maximum stress are displayed on display apparatus.